UNITED STATES
NUCLEAR REGULATORY COMMISSION
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June 20, 2002

MEMORANDUM TO: Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

FROM: Ashok C. Thadani, Director
Office of Nuclear Regulatory Research
Jack Strosnider for ACT 6/20/02

SUBJECT: RESEARCH INFORMATION LETTER 0202, REVISION OF 10 CFR 50.46 AND APPENDIX K

A significant amount of research has been performed since approval of the Emergency Core Cooling System (ECCS) rule in 1973. This research has enabled an improvement in the predictive capability and understanding of postulated accidents in nuclear power plants. In general, this research demonstrated the existence of a large safety margin between the regulatory acceptance limits and expected plant behavior during a loss-of-coolant accident (LOCA). As a result, 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," was amended in 1988 to allow the optional use of realistic physical models to analyze LOCAs. The basic 10 CFR 50.46 acceptance criteria were not revised in the 1988 rulemaking change and only minor revisions were made to Appendix K.

Because the 10 CFR 50.46 acceptance criteria are applicable to specific cladding alloys and the Appendix K models may contain some excessive conservatism, the staff in SECY-01-0133 [1] recommended "(A) changes to the technical requirements of the current 10 CFR 50.46 related to acceptance criteria and evaluation model(s) and (B) development of a voluntary risk-informed alternative to reliability requirements in 10 CFR 50.46."

Reference 1 also identified several possible changes that might be made in Appendix K. These were:

1. Implementing the 1994 ANS Decay Heat Standard.

2. Replacing the Baker-Just model for metal-water reaction with the Cathcart-Pawel model.

3. Deleting the requirement for steam cooling only for reflood rates of less than 1-inch per second.

4. Deleting the prohibition on return to nucleate boiling during blowdown.

Efforts related to items 1 through 4 above that were discussed in Reference 1 have been completed, and the purpose of this memorandum is to inform you of the findings. Findings

can be grouped into three areas; those that pertain to rulemaking and the 10 CFR 50.46 acceptance criteria, those that are related to rulemaking and a revised version of Appendix K, and those that are related to non-conservatisms in the existing Appendix K. This third set of findings can be pursued outside the rulemaking process of the first two areas.

Findings on 10 CFR 50 Acceptance Criteria for Rulemaking

First, it remains technically acceptable to retain all of the existing requirements in 10 CFR 50.46 and Appendix K in their present form as an option such that no model changes or reanalysis would be required. Thus, the current requirements and methods of analysis would be grandfathered.

Second, the peak cladding temperature limit and the maximum cladding oxidation limit in 10 CFR 50.46 could be replaced by a performance-based requirement that would be independent of the particular zirconium-based cladding alloy being considered. In particular, this performance-based approach could allow the deduced peak cladding temperature limit to be above the current 2200 °F limit, provided that assurance of fuel rod integrity throughout a LOCA is demonstrated. The 1 percent total hydrogen generation requirement may be deleted, since the combustible gas requirements are considered in 10 CFR 50.44, "Standards for combustible gas control system in light water-cooled power reactors." The other two acceptance criteria, Coolable Geometry and Long Term Cooling, are already performance-based and therefore need not be revised.

These revisions should provide valuable increases in operating margins without reducing fuel rod integrity due to a LOCA. Further, these revisions do not specify a particular zirconium-based cladding material. They are generic, and apply to all zirconium-based alloys. Thus, it will no longer be necessary to obtain an exemption in order to allow a new zirconium-based cladding.

Findings on Appendix K to 10 CFR 50 for Rulemaking

The technical efforts have shown that it is possible to replace correlations prescribed by Appendix K with correlations that are significantly more accurate. In doing so, some parameters are estimated more accurately, but this is accompanied by a reduction in overall analysis conservatism as might be expected.

As known conservatism is removed from Appendix K, there is the possibility that overall results produced by the revised Appendix K Evaluation Models might become non-conservative. Thus, there must be a process to ensure that calculations based on a revised version of Appendix K retain appropriate conservatism. This is consistent with the Commission Opinion for the original ECCS rule and with the conclusions rendered in SECY-86-318 [2], the Commission paper that ultimately resulted in the 1988 rule change. Provided that a process is established to ensure overall conservatism, it would be technically justifiable to make the following revisions:

(1) Replace the 1971 ANS decay heat standard with the 1994 ANS decay heat standard in a new optional Appendix K provided that there is an appropriate selection of user-specified values

and a determination of decay heat uncertainty. It is recommended that Regulatory Guide 1.157 [3] be updated to endorse the 1994 ANS Decay Heat Standard for use in a best estimate analysis. Details concerning application of the 1994 standard are described in Attachment 1.

(2) Replace the Baker-Just correlation with the Cathcart-Pawel correlation to account for heat release from the chemical reaction of steam with zirconium-based cladding materials in a new optional Appendix K. Regulatory Guide 1.157 could also be updated to endorse the Cathcart-Pawel model for calculating metal-water reaction heat release for all zirconium-based cladding alloys in a best estimate analysis. In all cases, an adjustment should be made to account for the effect of enhanced oxidation at high pressures when analyzing small break LOCAs. Calculation of cladding oxidation for comparison with the 17 percent limit should continue to be made with the Baker-Just correlation because that correlation was used in establishing the 17 percent limit. Attachment 2 contains a discussion of these changes.

(3) Delete the requirement for only reflood steam cooling for reflood rates less than one inch per second in a new, optional Appendix K. Attachment 3 discusses the basis for this change.

(4) Retain the prohibition on return to nucleate boiling during blowdown in a new, optional Appendix K. Attachment 3 discusses the basis for this recommendation.

Additional Findings Relevant to Appendix K Evaluation Models

The staff, in SECY-01-0133 [1] also recommended that an assessment of recognized non-conservatisms associated with Appendix K be performed. Non-conservatisms are un-modeled physical processes and simplifications now permitted under Appendix K that may result in an underprediction of the peak cladding temperature or the maximum cladding oxidation. Several non-conservatisms were identified as part of this effort. These include (a) subcooled and saturated boiling in a downcomer annulus during the reflood phase of a LOCA and the resulting void generation and phase separation, (b) downcomer entrainment and inventory reduction due to steam bypass during reflood, and (c) fuel relocation following cladding swelling during a temperature transient. New Evaluation Models making use of a revised, optional Appendix K should conservatively account for these processes.

The need for retaining some conservatism in the Evaluation Model has become quite clear in this recent work. As documented in Attachments 4 and 5, the suggested revisions and non-conservatisms have a significant effect on analysis results. Hence, within the regulatory framework, applicants making use of the new Appendix K should be required to ensure that the results are sufficiently and demonstratively conservative, and that the Evaluation Models appropriately account for non-conservatisms. Evaluation Models making use of the proposed revisions should be considered new Evaluation Models subject to a technical review.

Finally, it is recommended that a new Regulatory Guide be written to provide guidance to stakeholders on application of the 1994 ANS Decay Heat Standard and on a revised version of

Appendix K. The Regulatory Guide should discuss acceptable user selected inputs when using the 1994 ANS Standard and determination of decay heat uncertainty, and provide guidance on Evaluation Models using the new Appendix K. In addition, this Regulatory Guide should include sufficient guidance to ensure that appropriate levels of conservatism remain. This Regulatory Guide is expected to be useful to the industry as well as to the staff in making the review process efficient.

Coordination

The findings discussed by this memorandum have been presented to the ACRS Subcommittees on Materials and Metallurgy, Thermal-Hydraulic Phenomena, and Reliability & Probabilistic Risk Assessment. Drafts of this memorandum and its attachments were reviewed by NRR and ACRS, and their comments have been considered. Many of the findings were also discussed with interested stakeholders at a public meeting earlier this year.

Attachments: As stated

REFERENCES:

[1] SECY-01-0133, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 ECCS Acceptance Criteria," July 23, 2001.

[2] SECY-86-318, "Revision of the ECCS Rule Contained in Appendix K and Section 50.46 of 10 CFR Part 50," October 28, 1986

[3] USNRC Regulatory Guide 1.157, "Best Estimate Calculation of Emergency Core Cooling System Performance," May 1989.

Appendix K. One Regulatory Guide should discuss acceptable user selected inputs when using the 1994 ANS Standard and determination of decay heat uncertainty, and another Guide should discuss Evaluation Model requirements when using the new Appendix K. These Guides should be useful to the industry as well as to the staff in making the review process efficient.

Attachments: As stated

REFERENCES:

[1] SECY-01-0133, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 ECCS Acceptance Criteria," July 23, 2001.

[2] SECY-86-318, "Revision of the ECCS Rule Contained in Appendix K and Section 50.46 of 10 CFR Part 50," October 28, 1986

[3] USNRC Regulatory Guide 1.157, "Best Estimate Calculation of Emergency Core Cooling System Performance," May 1989.

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